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DRY FEED OF CHEMICALS IN WATER PURIFICATION

By W. F. Monfort

Dry feeding of chemicals has been practiced in American plants to a considerable extent for more than ten years. At St. Louis in 1903 and 1904 the advantage of avoiding bulky solutions of iron sulphate and milk of lime was appreciated and the method adopted by which the chemicals were dumped at five minute intervals into dissolving (or slaking) tanks and the solution or suspension applied to the influent water without further control. Later (1908) this method was modified by the use of clock operated automatic scales for lime, and a modified orifice feed for iron sulphate. The latter consists of a vertical orifice discharging upon a cylindrical drum revolving at a constant speed. Under test conditions with crushed and screened material its operation was satisfactory and its error small.

At Lancaster, Pennsylvania, a device was introduced which is thus referred to in *Engineering Record*, September, 1907.

> Originally designed for softening and coagulation with lime and soda ash, it was decided to make no change in hardness of the water, but to use alum and soda as dry powders which are thrown into the water by a distributing device actuated by a Poncelot undershot wheel operated by the water as it flows into the coagulating basin.

This was an adaptation of the principle involved in the Maignen apparatus (1884) for softening water by the use of a dry powder "Anti-calcaire."

Mr. Allen Hazen in *Engineering Record*, July 19, 1913, describes and illustrates a device for applying aluminum sulphate: A screw-conveyor is operated in the bottom of a hopper by a motor (electric or water). Variations in the speed of the screw are controlled, first, by a system of multiple gearing admitting of easy and wide change and, second, by changing the speed of the motor. This apparatus designed in 1907 by Mr. Hazen for Brisbane, Australia, was worked out in its mechanical details by Mr. R. S. Weston, who installed a copy at Knoxville, Tennessee. Mr. Hazen states that similar apparatus has been installed in a number of other plants with which he has had to do, and mentions the practical working of the device with aluminum sulphate and experimental success with calcium hypochlorite by the introduction of an "arrangement similar in construction to a meat chopper in the bottom of the hopper, above the screw, and operating it by the same motive power as the screw," to break up lumps and reduce the material to a size that can be handled by the screw.

In 1910 Mr. W. Donaldson devised an apparatus in which friction drive of a worm gear actuates the screw, permitting a nice adjustment of the weight of substance delivered through a wide range. Nine of these devices are in use in seven plants; eight, for applying hydrated lime, and one for sulphate of iron. Attempts to use it for soda ash have been unsatisfactory. Mr. Donaldson has made no publication concerning the apparatus, which seems worthy of a detailed description.

The matter of dry feed has been in the minds of many water works men for a number of years. What has been the genetic relation between the various developments mentioned, the writer will not undertake to say. It is probably true that the question has been in the air for a long period, and has received a wider consideration than any one has realized.

Perhaps some standardization of these devices may come about, such as has occurred in other apparatus for water treatment, filter control and the like, so that each user may not find it necessary to design throughout an apparatus for his particular need. In very large plants automatic scales are practical, as experience at St. Louis has demonstrated. For plants of medium and small size, dry feeding has proved feasible in a number of cases.

Regarding the measure of success which may be hoped for in any instance, the physical character of the material plays an important part. Mr. Hazen calls attention to the necessity of having sulphate of aluminum crushed to a smaller size than that ordinarily used, that it may be fed dry, and to the difficulty with calcium hypochlorite on account of its physical properties. It may be of interest to call attention to those specific properties of substances in common use, which affect their adaptability to this method of application.

The properties of a substance which affect its storage are closely related to the success of feeding devices. A model substance for application in this way should be uniform in size, constant in composition, permanent under prevailing conditions of temperature and pressure, and neither hygroscopic nor efflorescent.

Perhaps the most remote from this is calcium hypochlorite; because of its instability, its disagreeable odor, and its tendency to take up moisture, all of which connote loss of efficiency, as well as the mechanical difficulty of feeding regularly a more or less moist and lumpy material, dry feed for hypo seems impracticable.

Aluminum sulphate if fairly fine and uniform gives no trouble. It is stable at prevailing temperatures, not hygroscopic, does not cake, or bridge readily. Especially advantageous is dry feeding, as reducing to a minimum the corrosive action of a solution on pipes which convey it.

Hydrated lime of good quality for water treatment is now a commercial product, costing more of course than its equivalent of lump lime. But in many instances this excess would be almost or wholly met by the general simplification of the plant and the lowered cost of attendance.

As now manufactured it is air-separated and so uniform in size that 99.68 per cent will pass a 100-mesh, and 97.98 per cent a 200-mesh sieve. That it has a tendency to bridge over an orifice is a difficulty which has to be met where automatic scales are used in filling it into bags at the place of manufacture, as well as in the dry feed apparatus. The same trouble occurs with any fine amorphous material. Deterioration is proportional to the pressure of carbon dioxide to which it is exposed. This is ordinarily very small, save for purely local conditions. Because of its great uniformity it is especially well adapted to dry feed.

Lump lime is applied with automatic scales at St. Louis and at Columbus. The difficulty of adapting the scales to closely control coarse and fine material has not been wholly overcome. It is impossible to crush this material without fines, and wasteful to eliminate them. But the fines bridge as badly as hydrated lime, with resultant overloading and overdosing. Still a great improvement has been made within the past six years, and the method may be accounted successful. The storage problem in handling large quantities of lime is associated with the mechanical rather than with the chemical side, in that the upkeep of conveying machinery is the serious feature rather than deterioration in quality. If kept in bins that are practically air tight no deterioration occurs. It has long been known that carbonation occurs at ordinary temperature only after hydration. If, therefore, access of moist air into this material is prevented, carbonation prior to slaking will be nil. Dry feeding to slaking tanks discharging directly into the water to be treated has the advantage of space economy and of freedom from incrustation in pipe systems with troublesome stoppages.

With iron sulphate a difficulty arises in the physical behavior of the substance under temperature conditions occurring at some time during almost every day from June to late September. The ordinary pure sulphate contains seven molecules of water of crystallization. In behavior it is similar to copper sulphate, which furnishes the stock illustration of the Phase Rule to crystals of hydrated salts. It has been shown by Hofman and Wanjukow that at 21°C. (70° Fahr.) in a stream of air this crystal form loses three molecules of water and passes over into pale green crystals having but four molecules of water ($FeSO_4.4H_2O$) which at 80°C. (176° Fahr.) lose three molecules, undergo a transformation at 132°C. and begin to be oxidized very slowly at 167°C.; oxidation continues with the rise to 455°C. when conversion to $Fe_2O_32SO_3$ is complete, and the last molecule of water is expelled.

This first transition to $FeSO_4.4H_2O$ occurs to a limited extent in summer shipment in bags or in bulk, so that the material has a green gray appearance commonly. The extent to which alteration occurs does not greatly change the composition, only making analyses show a trifle more than 100 per cent of ferrous sulphate, ($FeSO_4.7H_2O$). But the slight efflorescence of exposed layer serves to inoculate the whole mass with the lower hydrate, facilitating the transformation.

If such a mass is stored in a closed bottle or other container at a temperature of 21°C. or slightly higher the resulting loss of water of crystallization in one part gives rise to a new trouble. The water vapor given off in the warmer layer is lighter than air; condensing on cooler particles, it is taken up by some pale green particles of the lower hydrate and in their re-crystallization in contact with other dark green ordinary crystals there is a cementing into masses of considerable size.

When iron sulphate is stored in large bins which are dust proof and almost air tight, a similar condition occurs. At St. Louis the bins are 20 feet in diameter and 40 feet deep. There have been times within the past six years when the whole content of a bin was in one mass. Again the bottom portion might be less firm than the upper, so that a cylindrical portion was supported over an air filled space below; or an opening about two feet in diameter remained surrounded by a cylinder whose walls were nine feet thick. Even in a smaller bin which was refilled at frequent intervals this caking occurred to such an extent that its effective holding capacity was limited to a nearly cylindrical vertical opening through the central portion. However, this caked material lost nothing but a modicum of water, and had suffered a concentration rather than a deterioration, since it has been shown that oxidation occurs only at high temperatures.

With a well designed crusher it can be prepared for dry feeding. It is necessary that a fair degree of uniformity be given this as any other material which is to be fed through an orifice. In July to September of 1913 when caked material was imperfectly crushed and fed, analyses of the solution checked against the volume of water (metered) gave results ranging as low as 45 per cent. The results were obtained with an orifice, where material and voids are measured together, and with material that was coarse, with more or less abundant lumps of all sizes.

It is therefore important in using dry feed for iron sulphate, that the material be fairly uniform or freshly crushed and fed from a small open hopper frequently filled. Under these conditions, which will be readily met in a plant of medium size, iron sulphate may be successfully fed, for the difficulties mentioned arise from storage in large bulk. In bags which permit the escape of liberated water vapor, serious caking from this cause has not been observed. It is probable that shallow bins open to the air would be less subject to troublesome caking than the deep and relatively narrow ones here referred to. Whether a dry feed machine or automatic scales are used should be determined by the size of the plant. For large plants undoubtedly the scales are best adapted as being less sensitive to size variation than an orifice device or a screw conveyor.

Whatever method of feeding iron sulphate be adopted consideration should be given to the possibility of growth of algae in the solution. So far as the writer is aware this has not been discussed, although doubtless others have noted such growth in moderately strong solutions of this neutral salt, as well as the common development in iron bearing waters carrying but a few parts per million of iron. In a solution of one and one-half pounds sulphate of iron per gallon, equivalent to more than 3700 parts of iron (Fe) per million, the growth at and near the surface was heavy and of such consistency that lumps of it breaking loose from the tank walls were firm enough to clog the outlet. It is inexpedient to use long pipe systems in conveying a solution in which such a growth may develop.

It is apparent that each substance presents the virtues and defects of its properties. It is essential that these be recognized and considered in adopting a method of feeding. Dry feed for alum, lime and iron sulphate offers certain advantages in permitting a reduction in the extent of pipes and the number of valves and fittings exposed to corrosion, incrustation, or stoppage from growths; economy of space in plant arrangement; a possible economy of attendance, and ready control of applied chemicals.